Investigate the Boundary Layer Features in Beijing During the SURF-2015 Field Campaign

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Introduction

The Study of Urban-impacts on Rainfall and Fog/haze (SURF), led by the Institute of Urban Meteorology, China Meteorological Administration (IUM, CMA) is planned for the 2015-2017 summer and winter, focusing on the Beijing-Tianjin-Hebei city cluster. As part of SURF-2015, a high-resolution Doppler lidar and an instrumented 325-m meteorological tower (Fig. 1), colocated in the Institute of Atmospheric Physics, Chinese Academy of Sciences (IAP, CAS), were used to sample the urban boundary layer (UBL) structure.

Objectives

- Determine urban PBL depth, an important variable for weather forecast and air quality modeling, under convective and nocturnal conditions
- Investigate the diurnal evolution of UBL

Lidar & Tower Data

- Lidar (Leosphere WindCube 100S) range is from 70-3000 m with 20-m vertical resolution. Only data satisfying the threshold carrier-to-noise ratio (CNR) of -20 dB were used.
- IAP tower sensors include 7-level 3-D sonic anemometers (Windmaster Pro) and open-path gas analyzers (LI-7500A) at 10-Hz frequency.
- Study period: 5-8 Jul & 12-13 Aug (only dates with complete lidar data)

1. Threshold method for convective BL

The lidar 30-m vertical velocity variance was used to determine the PBL depth. Following Barlow et al. (2011), threshold value is 0.1 m² s⁻² for an urban environment. An example of employing this threshold is shown in Fig. 3.

However, the threshold method failed to determine the nocturnal boundary layer (NBL), especially for late night (0000-0500 LST). This motivates to explore another techniques for estimating NBL depths.

2. Fractional method for nocturnal BL

The nocturnal turbulence regime for SURF-2015 is identified to be near-neutral regime based on the Sun et al. [2012] definition. Thus, we use a slightly altered version of the LeMone et al. [2014] method, which defines the NBL top as the height at which TKE decreases to a specific fraction of its near-surface maximum after subtracting out a "background" (free atmosphere) value (Fig. 4).

Conclusions & Future Work

The PBL evolution in urban areas is studied by combining 6-day Doppler lidar wind measurements and observations from the 325-m IAP tower during the summer SURF-2015 field campaign.

- We developed a composite method for estimating the PBL depths using the Doppler lidar.
  - CBL: \( \sigma_u^2 < 0.1 \text{ m}^2\text{s}^{-2} \)
  - NBL: \( \sigma_u^2 > 0.1 \left( \sigma_u^2 - \sigma_u^2_{\text{free}} \right) + \sigma_u^2_{\text{free}} \) where \( \sigma_u^2_{\text{free}} = 0.01 \text{ m}^2\text{s}^{-2} \)
  - The PBL depths determined by combining these methods have average values ranging from ~270 m to ~1500 m for the six days.
- Overall, the PBL evolution in urban areas is well captured by WRF-Urban with different PBL schemes, except for the QNSE scheme. The following tasks are planned:
  - Optimize the QNSE parameterization
  - Analyze the effects of Urban Canopy Models and regarding urban parameters on PBL evolution

References

LeMone et al. (2014), Objectively determined fair-weather NBL features in ARW-WRF and their comparison to CASES-97 observations. MWR, 142(8): 2709-2732.